carboline®
Coatings - Linings - Fireproofing

Firefilm Series
Firefilm III & IV

Carboline's Firefilm line of Intumescent Fire Resistive Materials offer superior fire protection for commercial and light industrial projects. These Firefilm systems allow architects to create unique exposed steel designs with unsurpassed aesthetics, durability and performance where fire resistance ratings are required. The Firefilm range of intumescent coatings provides high end architectural finishes and gives project planners options to develop specifications to meet all building types, project requirements and conditions.





Performance dashboard

Features & functionality

Durable finish – Provides a hard, impact and abrasion resistant surface.

Decorative Finish – Gives a smooth, decorative finish. Compatible topcoats available in a wide range of colors.

Best-in-class finish level and dozens of designs with Firefilm III

Fast recoat and ease of application with Firefilm IV

Visit Carboline for more product information

Firefilm III
Firefilm IV

Environment & materials

Improved by:

UL/ULC and ITS Listed – designs for many types of steel sections. Up to 3 hour fire ratings for both interior general purpose and interior conditioned space application

Advanced fiber free formulation - dust free surface

Declare, Red List Free

Certifications & rating systems:

Environmental Product Declaration (EPD)

LEED v4 VOC Compliant

ASTM E84 - UL 723 - Class A

SCAQMD Rule 1113 Compliant

Tested to meet (CDPH) Standard Method v1.2

MasterFormat® 07 81 23

Firefilm Series Guide Specs

For spec help, contact us or call 281.414.9710

See LCA, interpretation & rating systems

SM Transparency Report (EPD)™

VERIFICATION	LCA
3rd-party reviewed	✓
Transparency Report (EPD)	
3rd-party verified	✓

Validity: 20230213 – 20280212

Decl #: CAR-20230213-001

This environmental product declaration (EPD) was externally verified, according to NSF PCR for Architectural Coatings, and ISO 14025:2006, by Jack Geibig, President, Ecoform.

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SUMMARY

Reference PCR

NSF PCR for Architectural Coatings: NAICS 325510, 2022

Regions; system boundaries
North America; Cradle to grave

Functional unit / reference service life:
1 m^2 of covered and protected substrate; 60 years

LCIA methodology: TRACI 2.1

LCA software; LCI database
SimaPro Developer 9.4
EcoInvent 3.8, US-EI 2.2, and ELCD databases.

LCA conducted by: Sustainable Minds

Public LCA:
Life Cycle Assessment of Carboline Intumescent Fire-Resistive Materials

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314-644-1000

Contact us

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LCA results & interpretation

Firefilm Series

Life cycle assessment

Scope and summary

○ Cradle to gate ○ Cradle to gate with options ✓ Cradle to grave

Product description
Carboline's Firefilm series includes two products: Firefilm III and Firefilm IV. The impacts are presented for these two products covered in this report. Firefilm products are water-based thin-film, intumescent coating products for structural steel. They allow the designer to express the structure as an artform in buildings where fire resistance ratings are required. In a fire, they soften and expand to form thick meringue-like layers, which insulate the structure and protect the steel from fire.

Functional unit
The functional unit is **one square meter** of covered and protected substrate for a period of 60 years (the assumed average lifetime of a building).

Application and maintenance: Since Firefilm products fall under the primer designation and are applied to interior architecture, a 5-year market-based lifetime was adopted in the LCA models. One initial coating application and 11 recoats are required because the average life span of a building is assumed to be 60 years. The preferred waste management option for leftover paint is 100% landfilled.

Colorant: Colorants are not added to the fireproofing coatings themselves, neither at the point of sale nor at the point of application as defined in the application manuals and are therefore not included in the scope of this study.

Manufacturing data
Time coverage: The data covers annual manufacturing data for the 2021 calendar year from Carboline's manufacturing plant in Lake Charles, Louisiana. This period of time was chosen in order to capture a representative picture of businesses activities at Carboline.

Geographical coverage: The geographical coverage for this study is based on United States system boundaries for all processes and products.

Material composition greater than 1% by weight

MATERIAL	AVG %, WT.
Acid catalyst	25-35%
Resin	10-20%
Deionized water	10-20%
Pigment	10-20%
Spumific	5-10%
Carbon donor	5-10%
Additives	5-10%

Total impacts by life cycle stages [mPts/per func unit]



LIFE CYCLE STAGE	MPTS/FUNC. UNIT
Product stage	1.44E+01
Design and construction	6.03E-01
Use and maintenance	2.02E-02
End of life	4.80E-01

A variation of 10 to 20% | A variation greater than 20%

What's causing the greatest impacts

All life cycle stages
The product stage (Stage 1) accounts for the highest contribution to impacts, primarily because of the impacts associated with raw material manufacturing. The design & construction stage (Stage 2) is the next highest contributor for all impact categories except for global warming, smog, eutrophication, and carcinogenics. The use and maintenance stage (Stage 3) accounts for a minium contribution to almost all impact categories due to the low energy required for spray application.

Product stage
The raw material manufacturing phase (1-1) is the largest contributor for all impact categories. This holds true for the LCA results of each of Carboline's Firefilm products. Raw material manufacturing accounts for over 45% of the impact in each category for Firefilm III and accounts for over 60% of the impact in each category for Firefilm IV.

Design and construction
The design and construction stage (Stage 2) is the next highest contributor for most of the impact categories. This stage accounts for ~24% of ozone depletion for Firefilm III and ~16% of ozone depletion for Firefilm IV. The contributions to transportation are caused by the use of truck and trailer transportation.

Use and maintenance
It's worth noting that the VOC emissions released in the drying phase (phase 3-2) affect the variability in potential smog formation impacts. Different from the results of Firefilm IV, phase 3-2 is the second largest contributor to smog formation for Firefilm III. The reason for this difference is that Firefilm III emits about five times as much as VOCs that Firefilm III emits during the drying process.

End of life
For both Firefilm III and VI, the second highest impacts for the global warming, eutrophication, and carcinogenics categories come from the end-of-life stage (Stage 4).

Sensitivity analysis
A sensitivity analysis was performed to check the robustness of the results when the mass of specified raw materials was changed by +/-20%. These raw materials were chosen based on a combination of relatively higher contributions to the results.

Global warming potential was evaluated for sensitivity since Carboline is interested in the potential CO2-equivalent emissions of its products. The resulting variation in the total life cycle impacts is less than 10%, implying that the system is not sensitive to this assumed value.

Carboline is committed to finding new and efficient alternatives in manufacturing, raw material sourcing, and logistics to improve sustainability efforts. One of Carboline's most impactful contributions is the creation of the SLOB Program (slow moving and obsolete inventory). To reduce hazardous waste generation, the SLOB Program was designed to provide optics to Carboline's Inventory Analytics Team to review inventory close to expiration. Preventative measures are taken to rework inventory or sell this material at a discounted rate, with the ultimate goal of preventing little to zero waste of unused material. As an RPM company, Carboline is dedicated to working towards reaching the goals that have been set through RPM's Building a Better World Program. These goals include reducing energy consumption, landfill contributions, and water reuse/conservation opportunities.

See how we make it greener

LCA results

LIFE CYCLE STAGE	STAGE 1 PRODUCT STAGE	STAGE 2 DESIGN AND CONSTRUCTION	STAGE 3 USE AND MAINTENANCE	STAGE 4 END OF LIFE
Information modules: Included (X) | Excluded* (MND)	1-1 Raw material manufacturing	2-1 Transportation to distribution center	3-1 Coating application	4-1 Transportation to disposal site
No stages are excluded	1-2 Transportation of raw materials to plants	2-2 Transportation to point of sale	3-2 Emissions from drying	4-2 End-of-life management
	1-3 Coating manufacturing	2-3 Transportation to application site	3-3 Necessary maintenance and repaints	
				

SM Single Score

Learn about SM Single Score results

Impacts of the coating used for covering one square meter of substrate	9.31E+00 mPts	6.03E-01 mPts	2.02E-02 mPts	4.80E-01 mPts
Materials or processes contributing >20% to total impacts in each life cycle stage	Energy used for raw material extraction (electricity and fuels).	Trucks and trailer transportation (fuel consumption).	Energy and electricity consumed for coating application and recoats.	Landfill of the waste coating.

Firefilm III: TRACI v2.1 results per functional unit

LIFE CYCLE STAGE	STAGE 1 PRODUCT STAGE	STAGE 2 DESIGN AND CONSTRUCTION	STAGE 3 USE AND MAINTENANCE	STAGE 4 END OF LIFE
Ecological damage				
Impact category / Unit				
Acidification kg SO_2 eq	3.32E-01	1.74E-02	2.49E-04	1.93E-03
Eutrophication kg N eq	5.53E-02	3.62E-03	2.08E-05	1.39E-02
Global warming (embodied carbon) kg CO_2 eq	6.56E+01	1.00E+01	6.39E-02	1.83E+01
Ozone depletion kg CFC-11 eq	7.28E-06	2.38E-06	2.61E-09	2.73E-08
Human health damage				
Impact category / Unit				
Carcinogenics CTU_h	2.44E-06	9.18E-09	1.22E-10	7.18E-08
Non-carcinogenics CTU_h	8.41E-06	1.40E-06	2.06E-09	1.27E-07
Respiratory effects kg $PM_{2.5}$ eq	4.06E-02	3.50E-03	1.46E-05	1.54E-04
Smog kg O_3 eq	3.18E+00	2.23E-01	9.02E-01	2.67E-02
Additional environmental information				
Impact category / Unit				
Fossil fuel depletion MJ, LHV	1.21E+02	2.12E+01	8.43E-02	2.43E-01
Ecotoxicity CTU_e	8.31E+01	2.84E+01	4.82E-03	4.30E+00

See the additional content required by the NSF PCR for architectural coatings on page 4 of the **Transparency Report PDF**.

Firefilm IV: TRACI v2.1 results per functional unit

LIFE CYCLE STAGE	STAGE 1 PRODUCT STAGE	STAGE 2 DESIGN AND CONSTRUCTION	STAGE 3 USE AND MAINTENANCE	STAGE 4 END OF LIFE
Ecological damage				
Impact category / Unit				
Acidification kg SO_2 eq	4.02E-01	1.49E-02	2.33E-04	1.86E-03
Eutrophication kg N eq	6.08E-02	3.10E-03	1.95E-05	1.33E-02
Global warming (embodied carbon) kg CO_2 eq	7.75E+01 /td>	8.56E+00	5.99E-02	1.76E+01
Ozone depletion kg CFC-11 eq	1.06E-05	2.04E-06	2.45E-09	2.62E-08
Human health damage				
Impact category / Unit				
Carcinogenics CTU_h	3.80E-06	7.86E-09	1.14E-10	6.89E-08
Non-carcinogenics CTU_h	1.05E-05	1.20E-06	1.93E-09	1.22E-07
Respiratory effects kg $PM_{2.5}$ eq	4.97E-02	3.00E-03	1.37E-05	1.48E-04
Smog kg O_3 eq	3.61E+00	1.91E-01	1.50E-01	2.57E-02
Additional environmental information				
Impact category / Unit				
Fossil fuel depletion MJ, LHV	1.46E+02	1.81E+01	7.90E-02	2.33E-01
Ecotoxicity CTU_e	1.34E+02	2.43E+01	4.51E-03	4.13E+00

See the additional content required by the NSF PCR for architectural coatings on page 4 of the **Transparency Report PDF**.

References

LCA Background Report
Carboline Intumescent fireproofing coating LCA Background Report (public version), Carboline 2022; SimaPro Analyst 9.4; Ecoinvent 3.4 and US ecoinvent (US -EI 2.2) database; TRACI 2.1

PCRs

PCR for Architectural Coatings: NAICS 325510
Valid through Feb. 29, 2023. PCR review conducted by Thomas P. Gloria (Industrial Ecology Consultants), Ph. D; Mr. Bill Stough (Sustainable Research Group); Dr. Michael Overcash (Environmental Clarity).

NSF Program Operator Instructions

ISO 14025, "Sustainability in buildings and civil engineering works -- Core rules for environmental product declarations of construction products and services"

Download PDF SM Transparency Report, which includes the additional EPD content required by the NSF PCR.

SM Transparency Reports (TR) are ISO 14025 Type III environmental declarations (EPD) that enable purchasers and users to compare the potential environmental performance of products on a life cycle basis. Environmental declarations from different programs (ISO 14025) may not be comparable. In order to support comparative assertions, this EPD meets all comparability requirements stated in ISO 14025:2006. However, differences in certain assumptions, data quality, and variability between LCA data sets may still exist. As such, caution should be exercised when evaluating EPDs from different manufacturers, as the EPD results may not be entirely comparable. Any EPD comparison must be carried out at the building level per ISO 21930 guidelines. The results of this EPD reflect an average performance by the product and its actual impacts may vary on a case-to-case basis.

Rating systems

The intent is to reward project teams for selecting products from manufacturers who have verified improved life-cycle environmental performance.

LEED BD+C: New Construction | v4 - LEED v4
Building product disclosure and optimization
Environmental product declarations

○ Industry-wide (generic) EPD	½product
✓ Product-specific Type III EPD	1 product

LEED BD+C: New Construction | v4.1 - LEED v4.1
Building product disclosure and optimization
Environmental product declarations

○ Industry-wide (generic) EPD	1 product
✓ Product-specific Type III EPD	1.5 product

BREEAM New Construction 2018
Mat 02 - Environmental impacts from construction products
Environmental Product Declarations (EPD)

○ Industry-average EPD	.5 points
○ Multi-product specific EPD	.75 points
✓ Product-specific EPD	1 point

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Transparency Report (EPD)	
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Doc# /: CAR-20230213-001

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SUMMARY
Reference PCR
NSF PCR for Architectural Coatings: NAICS 325510, 2022
Regions; system boundaries
North America; Cradle to grave
Functional unit / reference service life:
1 m^2 of covered and protected substrate; 60 years
LCIA methodology: TRACI 2.1
LCA software; LCI database
SimaPro Developer 9.4
Ecoinvent 3.8, US-EI 2.2, and ELCD databases.
LCA conducted by: Sustainable Minds
Public LCA:
Life Cycle Assessment of Carboline Intumescent Fire-Resistive Materials

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How we make it greener

Firefilm Series

Collapse all

See LCA results by life cycle stage

RAW MATERIAL ACQUISITION

Carboline is dedicated to improving raw material sustainability efforts. These initiatives include researching alternative methods to acquire raw materials, while being conscience of their environmental impact and opting for suppliers who place emphasis on sustainable manufacturing techniques/renewable energy processes.



TRANSPORTATION

In an effort to reduce multiple long distance LTL shipments, Carboline has initiated pooling orders from local warehousing sites vs. shipping individual orders from multiple manufacturing and warehousing locations throughout the country.



MANUFACTURING

Carboline is always exploring solutions to reduce energy usage throughout the production process. Some of these initiatives include –

- Installing VFD drives to reduce electrical usage for mixing units
- Upgrading air driers with the intent of generating better air, which could result in using less air in the production process
- Researching solar installation at Carboline's Dayton, Nevada manufacturing site



END OF LIFE

Carboline fireproofing products provide long-term protection to the structures to which they are applied and were designed to outlive the expected lifespan of a building. Essentially, the only waste generated is at the time of demolition or if any repairs need to be made to the building.



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VERIFICATION	LCA
3rd-party reviewed	✓
Transparency Report (EPD)	
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Validity: 20230213 – 20280212

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Additional EPD content required by: NSF PCR: Architectural Coatings

Firefilm Series

Data

Background This product-specific declaration was created by collecting life cycle data for the Firefilm Series covering 1 m^2 of substrate for a period of 60 years (the assumed average lifetime of a building). Databases adopted in the model include ecoinvent v3, US-EI 2.2, and ELCD databases.

Allocation The allocation methods used were examined according to the allocation rules in the NSF PCR for Architectural Coatings. The only manufacturing input that needed allocation was electricity since there is only one single meter that includes the production of multiple Carboline IFRM products. The allocation of electricity was based on the percentage of production for individual products divided by total site production output. In addition, there is no co-product produced in the manufacturing process.

Cut-off criteria A minimum of 95% of the total mass, energy, and environmental relevance for the system were captured. The total of neglected input flows per module does not exceed 5% of energy, mass, and environmental impacts. The cut-off rules do not apply to hazardous and toxic properties, which must be listed even when the given process unit is under the cut-off criterion. No known flows are deliberately excluded from this declaration; therefore, these criteria have been met. No biogenic carbon enters the product system.

Quality All primary data were collected for one year to ensure representativeness of annual business activities and post-consumer contents. Except for overseas transportation, secondary datasets for the US were used since Carboline products are expected to be applied in the US. The overall quality of the data used in this study is considered to be good and representative of the described systems.

Major system boundary exclusions:

- Capital goods & infrastructure; maintenance and operation of support equipment;
- Manufacture & transport of packaging materials not associated with final product;
- Human labor and employee transport;
- Building operational energy and water use not associated with final product.

Major assumptions and limitations:

- Material input and transportation distances are averages and do not reflect changes in material efficiency and supplier locations.
- Proxy materials were used when matching secondary data sets were not identified.
- Generic data sets used for material inputs, transport, and waste processing are considered good quality, but actual inputs from material suppliers, transport carriers, and local waste processing may vary.
- LCA results are relative expressions and do not predict impacts on category endpoints, the exceeding of thresholds, safety margins or risks.

Relevant technical properties

PRODUCT	Firefilm III	Firefilm IV	Unit
Density	1.45	1.50	kg/L
Dry Film Thickness (DFT) / coat	30	28	mils
Reference flow per functional unit	8.94	8.58	kg
Packaging for finished products	Steel pail	Steel pail	–
Packaging volume	18.9	18.9	L

Scenarios and additional technical information

PARAMETER (for 1 kg finished product)	VALUE	UNIT

Design and construction [Stage 2]

Vehicle type	Lorry, 16-32 ton	
Average packaging weight for 1 kg coating		
Firefilm III	0.049	kg
Firefilm IV	0.048	
Distance from manufacturer to distribution center		
Firefilm III	2685.4*	km
Firefilm IV	2308.9*	km
Distance from distribution center to point of sale	804.5	km
Distance from point of sale to application site	0	km

*Average transportation distances between the manufacturing plant and the distribution centers were provided by Carboline based on sales data.

Use and maintenance [Stage 3]

Application scrap assumed	10	%
Spray equipment assumed	Graco Mark V Airless	
Electricity consumption	2.09	kWh
Sprayer flow rate	1	gpm
Waste materials at the application site before waste processing (product scrap and packaging waste)		
Product scrap	0.1	kg
Packaging waste recycling - Firefilm III	0.049	kg
Packaging waste recycling - Firefilm IV	0.048	kg
Output materials from on-site waste processing	0	kg
Biogenic carbon contained in packaging	0	kg CO_2
VOC emissions from drying - Firefilm III (EPA Method 24)	2	g/L
VOC emissions from drying - Firefilm IV (EPA Method 24)	4	g/L

Necessary maintenance and repairs

Product life for functional unit		60	years
Coating type/environment		Indoor	
Market-based lifetime		5	years
Initial coating application		1	time
Maintenance recoat		11	times
No colorants are added		–	–

End of life [Stage 4]

Assumptions for scenario development	Manual deconstruction, sent for landfill by truck		
End-of-life products (landfill)	Collected with mixed construction waste	1	kg
	Reuse	0	kg
Recovery	Recycling	0	kg
	Landfill	0	kg
Waste transport (landfill)		11.27	km
Removals of biogenic carbon (excluding packaging)		0	kg CO_2

Firefilm III: LCIA results, resource use, output and waste flows, and carbon emissions & removals per functional unit

Parameter	Unit	Stage 1 - Product stage			Stage 2 - Design and construction			Stage 3 - Use and maintenance			Stage 4 - End of life		Total
		1-1	1-2	1-3	2-1	2-2	2-3	3-1	3-2	3-3	4-1	4-2	
LCIA results (per m^2 covered and protected substrate for a period of 60 years)													
Ozone depletion	kg CFC-11 eq	3.12E-06	1.89E-06	2.67E-07	1.83E-06	5.49E-07	0	2.18E-10	0	2.40E-09	7.69E-09	1.96E-08	**9.70E-06**
Global warming	kg CO_2 eq	5.13E+01	7.99E+00	6.33E+00	7.69E+00	2.31E+00	0	5.32E-03	0	5.86E-02	3.23E-02	1.83E+01	**9.40E+01**
Smog	kg O_3 eq	2.50E+00	4.53E-01	2.19E-01	1.72E-01	5.14E-02	0	1.78E-04	8.99E-01	1.96E-03	7.20E-04	2.60E-02	**4.33E+00**
Acidification	kg SO_2 eq	2.82E-01	2.97E-02	2.02E-02	1.34E-02	4.01E-03	0	2.08E-05	0	2.28E-04	5.61E-05	1.88E-03	**3.51E-01**
Eutrophication	kg N eq	4.95E-02	3.37E-03	2.37E-03	2.79E-03	8.35E-04	0	1.73E-06	0	1.91E-05	1.17E-05	1.38E-02	**7.28E-02**
Carcinogenics	CTUh	2.12E-06	7.14E-09	3.14E-07	7.06E-09	2.12E-09	0	1.02E-11	0	1.12E-10	2.96E-11	7.17E-08	**2.52E-06**
Non-carcinogenics	CTUh	7.14E-06	1.04E-06	2.19E-07	1.08E-06	3.24E-07	0	1.71E-10	0	1.88E-09	4.53E-09	1.23E-07	**9.94E-06**
Respiratory effects	kg $PM_{2.5}$ eq	3.34E-02	3.59E-03	3.65E-03	2.70E-03	8.08E-04	0	1.22E-06	0	1.34E-05	1.13E-05	1.42E-04	**4.43E-02**
Ecotoxicity	CTUe	5.60E+01	2.09E+01	6.12E+00	2.18E+01	6.55E+00	0	4.01E-04	0	4.41E-03	9.56E-02	4.20E+00	**1.16E+02**
Fossil fuel depletion	MJ surplus	9.75E+01	1.68E+01	6.77E+00	1.63E+01	4.89E+00	0	7.02E-03	0	7.73E-02	6.84E-02	1.75E+01	**1.43E+02**
Resource use indicators													
Renewable primary energy used as energy carrier (fuel)	MJ, LHV	3.31E+01	1.07E+01	1.60E+00	1.04E+01	3.11E-02	0	5.68E-03	0	6.25E-02	4.36E-04	1.38E-03	**3.50E+01**
Renewable primary resources with energy content used as material	MJ, LHV	1.54E+01	3.90E-02	2.29E+00	3.79E-02	1.14E-02	0	1.75E-03	0	1.93E-02	1.59E-04	4.72E-04	**1.78E+01**
Total use of renewable primary resources with energy content	MJ, LHV	4.84E+01	1.46E-01	3.89E+00	1.42E-01	4.25E-02	0	7.43E-03	0	8.18E-02	5.95E-04	1.86E-03	**5.27E+01**
Non-renewable primary resources used as an energy carrier (fuel)	MJ, LHV	9.33E+02	1.12E+02	9.64E+01	1.09E+02	3.26E+01	0	9.58E-02	0	1.05E+00	4.57E-01	1.15E+00	**1.29E+03**
Non-renewable primary resources with energy content used as material	MJ, LHV	9.33E+02	1.12E+02	9.64E+01	1.09E+02	3.26E+01	0	9.58E-02	0	1.05E+00	4.57E-01	1.15E+00	**1.29E+03**
Total use of renewable primary resources with energy content	MJ, LHV	9.33E+02	1.12E+02	9.64E+01	1.09E+02	3.26E+01	0	9.58E-02	0	1.05E+00	4.57E-01	1.15E+00	**1.29E+03**
Hazardous waste disposed	kg	0	0	1.58E+00	0	0	0	0	0	0	0	0	**1.58E+00**
Non-hazardous waste disposed	kg	0	0	1.68E-01	0	0	0	0	0	0	0	0	**1.68E-01**
Hydro/wind power	MJ, LHV	0	0	7.51E-01	0	0	0	0	0	0	0	0	**7.51E-01**
Fossil energy	MJ, LHV	0	0	1.48E+01	0	0	0	0	0	0	0	0	**1.48E+01**
Bio-energy	MJ, LHV	0	0	4.72E-01	0	0	0	0	0	0	0	0	**4.72E-01**
Nuclear- energy	MJ, LHV	0	0	5.15E+00	0	0	0	0	0	0	0	0	**5.15E+00**
Other-energy	MJ, LHV	0	0	2.58E-01	0	0	0	0	0	0	0	0	**2.58E-01**
Renewable secondary fuels	MJ, LHV	0	0	0	0	0	0	0	0	0	0	0	**0**
Non-renewable secondary fuels	MJ, LHV	0	0	0	0	0	0	0	0	0	0	0	**0**
Recycled materials	kg	0	0	0	0	0	0	0	0	0	0	0	**0**
Recovered energy	MJ, LHV	0	0	0	0	0	0	0	0	0	0	0	**0**
Secondary materials	kg	0	0	0	0	0	0	0	0	0	0	0	**0**
Use of net fresh water resources	m^3	1.18E+02	1.81E+00	2.98E+00	1.76E+00	5.27E-01	0	1.78E-04	0	1.95E-03	7.38E-03	2.31E-02	**1.25E+02**
Output flows and waste category indicators													
High-level radioactive waste, conditioned, to final repository	kg	8.67E-03	3.90E-05	4.98E-04	3.75E-05	1.12E-05	0	3.71E-07	0	4.08E-06	1.57E-07	5.92E-07	**9.26E-03**
Intermediate- and low-level radioactive waste, conditioned, to final repository	kg	3.23E-05	1.66E-05	4.06E-06	1.61E-05	4.83E-06	0	4.09E-09	0	4.50E-08	6.76E-08	1.72E-07	**7.42E-05**
Components for re-use	kg	0	0	0	0	0	0	0	0	0	0	0	**0**
Materials for recycling	kg	0	0	0	0	0	0	0	0	0	0	0	**0**
Materials for energy recovery	kg	0	0	0	0	0	0	0	0	0	0	0	**0**
Exported energy	MJ, LHV	0	0	0	0	0	0	0	0	0	0	0	**0**
Carbon emissions and removals													
Biogenic carbon removal from product	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	**0**
Biogenic carbon emission from product	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	**0**
Biogenic carbon removal from packaging	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	**0**
Biogenic carbon emission from packaging	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	**0**
Biogenic carbon emission from combustion of waste from renewable sources used in production processes	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	**0**
Calcination carbon emissions	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	**0**
Carbonation carbon removals	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	**0**
Carbon emissions from combustion of waste from non-renewable sources used in production processes	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	**0**

Firefilm IV: LCIA results, resource use, output and waste flows, and carbon emissions & removals per functional unit

Parameter	Unit	Stage 1 - Product stage			Stage 2 - Design and construction			Stage 3 - Use and maintenance			Stage 4 - End of life		Total
		1-1	1-2	1-3	2-1	2-2	2-3	3-1	3-2	3-3	4-1	4-2	
LCIA results (per m^2 covered and protected substrate for a period of 60 years)													
Ozone depletion	kg CFC-11 eq	8.93E-06	1.44E-06	2.47E-07	1.51E-06	5.27E-07	0	2.04E-10	0	2.25E-09	7.38E-09	1.88E-08	**1.27E-05**
Global warming	kg CO_2 eq	6.59E+01	6.04E+00	5.55E+00	6.35E+00	2.21E+00	0	4.99E-03	0	5.49E-02	3.10E-02	1.75E+01	**1.04E+02**
Smog	kg O_3 eq	3.21E+00	2.01E-01	2.02E-01	1.42E-01	4.94E-02	0	1.67E-04	1.48E-01	1.84E-03	6.91E-04	2.50E-02	**3.98E+00**
Acidification	kg SO_2 eq	3.69E-01	1.43E-02	1.86E-02	1.10E-02	3.85E-03	0	1.94E-05	0	2.14E-04	5.38E-05	1.80E-03	**4.19E-01**
Eutrophication	kg N eq	5.66E-02	2.30E-03	1.99E-03	2.30E-03	8.01E-04	0	1.62E-06	0	1.79E-05	1.12E-05	1.33E-02	**7.73E-02**
Carcinogenics	CTUh	3.51E-06	5.50E-09	2.94E-07	5.83E-09	2.03E-09	0	9.52E-12	0	1.05E-10	2.84E-11	6.89E-08	**3.88E-06**
Non-carcinogenics	CTUh	9.44E-06	8.29E-07	2.01E-07	8.92E-07	3.11E-07	0	1.61E-10	0	1.77E-09	4.35E-09	1.18E-07	**1.18E-05**
Respiratory effects	kg $PM_{2.5}$ eq	4.40E-02	2.31E-03	3.41E-03	2.22E-03	7.75E-04	0	1.14E-06	0	1.25E-05	1.09E-05	1.37E-04	**5.29E-02**
Ecotoxicity	CTUe	1.12E+02	1.67E+01	5.68E+00	1.80E+01	6.28E+00	0	3.76E-04	0	4.14E-03	8.79E-02	4.04E+00	**1.63E+02**
Fossil fuel depletion	MJ surplus	1.27E+02	1.28E+01	6.22E+00	1.35E+01	4.69E+00	0	6.58E-03	0	7.24E-02	6.57E-02	1.68E-01	**1.65E+02**
Resource use indicators													
Renewable primary energy used as energy carrier (fuel)	MJ, LHV	3.61E+01	8.14E-02	1.47E+00	8.57E-02	2.99E-02	0	5.32E-03	0	5.86E-02	4.18E-04	1.33E-03	**3.78E+01**
Renewable primary resources with energy content used as material	MJ, LHV	2.61E+01	2.96E-02	2.71E+00	3.13E-02	1.09E-02	0	1.64E-03	0	1.81E-02	1.52E-04	4.53E-04	**2.83E+01**
Total use of renewable primary resources with energy content	MJ, LHV	6.21E+01	1.11E-01	3.58E+00	1.17E-01	4.07E-02	0	6.96E-03	0	7.66E-02	5.70E-04	1.78E-03	**6.61E+01**
Non-renewable primary resources used as an energy carrier (fuel)	MJ, LHV	1.19E+03	8.53E+01	8.86E+01	8.98E+01	3.13E+01	0	8.98E-02	0	9.87E-01	4.38E-01	1.10E+00	**1.48E+03**
Non-renewable primary resources with energy content used as material	MJ, LHV	9.71E-01	2.56E-04	4.10E-03	2.69E-04	9.36E-05	0	7.65E-10	0	8.41E-09	1.31E-06	6.28E-06	**9.76E-01**
Total use of non-renewable primary resources with energy content	MJ, LHV	1.19E+03	8.53E+01	8.86E+01	8.98E+01	3.13E+01	0	8.98E-02	0	9.87E-01	4.38E-01	1.10E+00	**1.49E+03**
Hazardous waste disposed	kg	0	0	1.48E+00	0	0	0	0	0	0	0	0	**1.48E+00**
Non-hazardous waste disposed	kg	0	0	1.56E-01	0	0	0	0	0	0	0	0	**1.56E-01**
Hydro/wind power	MJ, LHV	0	0	7.02E-01	0	0	0	0	0	0	0	0	**7.02E-01**
Fossil energy	MJ, LHV	0	0	1.39E+01	0	0	0	0	0	0	0	0	**1.39E+01**
Bio-energy	MJ, LHV	0	0	4.41E-01	0	0	0	0	0	0	0	0	**4.41E-01**
Nuclear- energy	MJ, LHV	0	0	4.82E+00	0	0	0	0	0	0	0	0	**4.82E+00**
Other-energy	MJ, LHV	0	0	2.41E-01	0	0	0	0	0	0	0	0	**2.41E-01**
Renewable secondary fuels	MJ, LHV	0	0	0	0	0	0	0	0	0	0	0	**0**
Non-renewable secondary fuels	MJ, LHV	0	0	0	0	0	0	0	0	0	0	0	**0**
Recycled materials	kg	0	0	0	0	0	0	0	0	0	0	0	**0**
Recovered energy	MJ, LHV	0	0	0	0	0	0	0	0	0	0	0	**0**
Secondary materials	kg	0	0	0	0	0	0	0	0	0	0	0	**0**
Use of net fresh water resources	m^3	1.32E+02	1.32E+00	2.50E+00	1.39E+00	4.85E-01	0	1.66E-04	0	1.83E-03	6.79E-03	2.44E-02	**1.37E+02**
Output flows and waste category indicators													
High-level radioactive waste, conditioned, to final repository	kg	9.83E-03	2.94E-05	4.60E-04	3.09E-05	1.08E-05	0	3.48E-07	0	3.82E-06	1.51E-07	5.69E-07	**1.04E-02**
Intermediate- and low-level radioactive waste, conditioned, to final repository	kg	3.75E-05	1.26E-05	3.73E-06	1.33E-05	4.63E-06	0	3.83E-09	0	4.22E-08	6.49E-08	1.66E-07	**7.21E-05**
Components for re-use	kg	0	0	0	0	0	0	0	0	0	0	0	**0**
Materials for recycling	kg	0	0	0	0	0	0	0	0	0	0	0	**0**
Materials for energy recovery	kg	0	0	0	0	0	0	0	0	0	0	0	**0**
Exported energy	MJ, LHV	0	0	0	0	0	0	0	0	0	0	0	**0**
Carbon emissions and removals													
Biogenic carbon removal from product	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	**0**
Biogenic carbon emission from product	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	**0**
Biogenic carbon removal from packaging	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	**0**
Biogenic carbon emission from packaging	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	**0**
Biogenic carbon emission from combustion of waste from renewable sources used in production processes	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	**0**
Calcination carbon emissions	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	**0**
Carbonation carbon removals	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	**0**
Carbon emissions from combustion of waste from non-renewable sources used in production processes	kg CO_2	0	0	0	0	0	0	0	0	0	0	0	**0**

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